Taxonomy Working Group Final Report

January 20, 2006

VOLUME I: REPORT

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1.0 Authorization

The Office of Chief Engineer requested that the NASA Engineering and Safety Center (NESC) lead a small group to develop a proposal for a common taxonomy to be used by all NASA projects in the classifying of nonconformances, anomalies, and problems. The intent was to determine what information is required to be collected and maintained in order to facilitate trending and root cause analyses in addition to assisting individual problem resolution. This task was within the scope of NESC's charter, where NESC is tasked with performing "independent safety and engineering trend analyses and technical risk assessments utilizing program and discipline data sources and state-of-the-art tools and techniques while looking for trends across and within programs."

2.0 Signature Page

Rober Beil, Co-chair	Vickie Parson, C-chair
Tina Panontin	Roxana Wales
Michael Rackley	James Milne
Tim Barth	John McPherson
Mark Terrone	Jayne Dutra
Larry Shaw	

3.0 List of Team Members

NASA personnel with diverse experience in both human space flight and robotic missions were recruited to participate in this activity. Team members had expertise in knowledge management systems, anomaly resolution, trending, current problem reporting systems, and taxonomy development. Managers at the various centers endorsed this work by funding their employees' participation. The team consisted of:

Team Members

Name	Center Affiliation
Vickie Parsons	NESC, LaRC
Robert Beil	NESC, KSC
Tina Panontin	ARC
Roxana Wales	ARC
Michael Rackley	GSFC
James Milne	GSFC
Tim Barth	KSC
John McPherson	MSFC
Mark Terrone	NESC, KSC
Jayne Dutra	JPL
Larry Shaw	JSC
Support	
Elizabeth Holthofer	ViGYAN, Inc., LaRC

4.0 Executive Summary

The purpose of the Taxonomy Working Group was to develop a proposal for a common taxonomy to be used by all NASA projects in the classifying of nonconformances, anomalies, and problems. Specifically, the group developed a recommended list of data elements along with general suggestions for the development of a problem reporting system to better serve NASA's need for managing, reporting, and trending project aberrant events.

The definitions, suggested values, and prescriptions for various fields provided in this report and the appendices are guidelines for future (and existing) NASA projects. The authors recognize that individual projects have needs that may require a finer dissection of the data, while others may need less information to adequately manage their nonconformances, anomalies, and problems. The bottom line is that there is a critical need for projects to capture information on aberrant events in order to determine the causes and prevent future occurrences. Where an individual project captures the data in a different format, the relevant data needs to be translated into the shared data elements and provided to a common source so that trending across projects may be accomplished by independent organizations such as the NESC. Submittal of this report to NESC and Office of Chief Engineer management concludes the work of the Taxonomy Working Group and this team will be dissolved. Finally, it is advisable to have an expert panel 'scrub' the taxonomy of existing field codes to ensure they are accurate, complete, and unambiguous. This panel should include experts in taxonomy development as well as experts in problem reporting for major NASA programs. They should also ensure that Cause Codes refer only to causes, Defect Codes only to defects, etc.

5.0 A/I/C Plan

Not applicable.

6.0 Description of the Problem and Proposed Solutions

Purpose

The purpose of the Taxonomy Working Group was to develop a proposal for a common taxonomy to be used by all NASA projects in the classifying of nonconformances, anomalies, and problems. Specifically, the group developed a recommended list of data elements along with general suggestions for the development of a problem reporting system to better serve NASA's need for managing, reporting, and trending project aberrant events. Since a taxonomy is a controlled term list, not a data architecture for a particular system, the intent was not to design a problem reporting system. However, the recommendations within this document may serve as a partial guide to system developers in the future.

Proposed Solution

Appendix A provides details of the data elements recommended for any NASA project to collect and maintain for nonconformances, anomalies, and problems. The generic formats for each data element and suggested taxonomies or potential values are also included in Appendix A. This complete set of data elements should provide enough information to facilitate the root cause and trend analysis required of the individual projects by NPR 7120.5C. Data elements marked with an asterisk in the share column represent the minimum set of data elements that all projects must make available through a common user interface to organizations, such as NESC, tasked with performing independent trending across projects. With the understanding that some projects currently have systems that do not contain all these asterisk items, some reduction in this requirement is identified within Appendix A by indicating which of those data elements would only be required of new projects or as applicable (marked as 'New' in the shared field). Additionally, given the differences between human spaceflight and robotic mission life cycles and post launch activities, some reduction in data elements may be further requested. Appendix A is the starting point from which individual programs and projects should develop their data requirements and problem reporting systems. Where pick lists or taxonomies are provided for individual data elements, these are meant to be suggestions and may not be comprehensive as a project determines the necessary values when their actual system is being developed. However, certain coding schemes (i.e., criticality codes) should be consistent from one program to another in order to facilitate comprehensive NASA trending. Also, the Taxonomy Working Group identified individual data elements within Appendix A according to when the data would most likely be available for entry into a problem reporting system (initiation, analysis, or closeout). Appendix B provides a summary of the characteristics of a good taxonomy for project reference when further developing their individual systems.

7.0 Data Analysis (Refer to Appendices for additional information).

Not applicable

8.0 Recommendations

Appendix A provides details of the data elements recommended for any NASA project to collect and maintain for nonconformances, anomalies, and problems. The generic formats for each data element and suggested taxonomies or potential values are also included in Appendix A. This complete set of data elements should provide enough information to facilitate the root cause and trend analysis required of the individual projects by NPR 7120.5C. Data elements marked with an asterisk in the share column represent the minimum set of data elements that all projects must make available through a common user interface to organizations, such as NESC, tasked with performing independent trending across projects. With the understanding that some projects currently have systems that do not contain all these asterisk items, some reduction in this requirement is identified within Appendix A by indicating which of those data elements would only be required of new projects or as applicable (marked as 'New' in the shared field). Additionally, given the differences between human spaceflight and robotic mission life cycles and post launch activities, some reduction in data elements may be further requested. Appendix A is the starting point from which individual programs and projects should develop their data requirements and problem reporting systems. Where pick lists or taxonomies are provided for individual data elements, these are meant to be suggestions and may not be comprehensive as a project determines the necessary values when their actual system is being developed. However, certain coding schemes (i.e., criticality codes) should be consistent from one program to another in order to facilitate comprehensive NASA trending. Also, the Taxonomy Working Group identified individual data elements within Appendix A according to when the data would most likely be available for entry into a problem reporting system (initiation, analysis, or closeout). Appendix B provides a summary of the characteristics of a good taxonomy for project reference when further developing their individual systems.

In addition to the main deliverables provided in Appendices A and B, the Taxonomy Working Group makes the following recommendations as projects begin developing their problem reporting systems.

<u>Recommendations</u>

R-1 Projects should require that every contractor/vendor/civil servant enter ALL anomalies into a common system for the project rather than have different systems for different levels of aberrant events. Maintaining all project data on nonconformances, anomalies, and problems within one system will facilitate trending and early identification of potential problems. Additionally, it allows universal access to the data ensuring commonality.

R-2 Problem reporting systems should be seamlessly integrated/linked with other databases such as Failure Mode and Effects Analysis (FMEA), critical items list (CIL), Hazard, Mishap/ Incident Reporting Information System (IRIS), hardware, Government/Industry

Data Exchange Program (GIDEP), logistics systems, and action item tracking systems for the sharing of pertinent information.

R-3 NASA should utilize their contract negotiations to require standardization across vendors for part numbers and naming conventions.

R-4 NASA should consider a database of common hardware to include information on life cycles and use times.

<u>Best Practices</u>

1 Problem reporting systems should be designed to generate actions based on certain values in critical fields and populate a standard action item tracking system automatically.

2 Problem reporting systems should insure that all related data is visible and usable with no hidden data.

3 Problem reporting systems should be designed to allow searches for specific values within fields.

4 Problem reporting systems should be designed to automatically complete related fields where possible rather than require manual entry. For example, where the criticality code is known from other data systems, the problem reporting system should import it rather than requiring the user to create it. Also, it is recommended that for information about NASA employees and contractors, problem reporting systems use the POPS2: People, Organizations, Projects, Skills schema that is incorporated into the National Institute for Science Education (NISE) metadata framework and implemented into the Lightweight Directory Access Protocol (LDAP) Directory. The schema includes information about Competency, Location, Title, Contact Information, Organization and Employee Number. The uniform resource locator (URL) with specific schema information is available with a password as a Raw Data File (RDF) file at this location: http://lurch.hq.nasa.gov/2005/11/21/pops.owl

5 Problem reporting systems should employ pick lists and eliminate the use of meaningless data codes.

6 Wherever appropriate, pick list fields should allow multiple choices rather than force the user to determine one option.

7 Wherever appropriate, pick lists should include the option to enter something under an “other” category in the event that the pick list is not comprehensive.

8 Problem reporting systems should include prompts, explanations, and examples within the free form text fields to guide the user towards a good entry. Suggestions for several key fields are provided in Appendix C.

9 Problem reporting systems should include the ability for updates to individual fields as more information is obtained. For example, the problem description may require several updates as the investigation proceeds and more data is gathered. The system should automatically maintain an archival record and update log as new entries are made and/or updated. Problem reporting systems should be designed to keep configuration control of individual problem records and easily identify when the record was last updated and by whom.

10 Problem reporting systems should include logic to guide the user in data entry and preclude entry of impossible combinations. The underlying databases beneath problem reporting systems, through what are called ‘business rules’ in the information technology (IT) community, should be burdened with the task of enforcing that all such fields are filled in at the appropriate stage in the problem report life-cycle, as required. When ‘other’ is selected for a given code, the database should then prompt for a textual description of the actual cause, defect, etc.

11 Problem reporting systems should have embedded help information and tutorials to enhance usability for reporters, analysts, and managers.

12 Problem reporting systems should include the capability to attach related documents, pictures, figures, etc.

9.0 Lessons Learned

Not applicable.

10.0 Definition of Terms

Clarification Definitions

It was evident from the discussions within the Taxonomy Working Group that NASA needed common definitions for what constitutes the various aberrant events. Therefore, these definitions are provided for consideration in a future NASA Guidebook:

Problem: An adverse situation, event, or condition that exists at a specific moment in time; any adverse event or condition that requires attention, resources, time, and/or effort to resolve.

Nonconformance: Condition where an item has failed to comply with specified requirements.

Anomaly: An unexpected event, hardware or software damage, a departure from established procedures or performance, or a deviation of system, subsystem, and/or hardware or software performance outside certified or approved design/performance specification limits

Remedial Action: Action taken to make the aberrant article or material acceptable for use.

Recurrence Control: Preventive measures to significantly reduce the likelihood, mitigate the adverse effects or effectively eliminate the possibility of recurrence of a aberrant condition

Corrective Action: Correction, replacement, repair, or authorized disposition of noncompliant items/conditions, implementation of preventive measures to eliminate the causes of noncompliance, and validation that implemented preventive measures have effectively eliminated recurrence of the aberrant condition

11.0 List of Acronyms

ARC	Ames Research Center
CIL	Critical Items List
FMEA	Failure Mode and Effects Analysis
GIDEP	Government/Industry Data Exchange Program
GSFC	Goddard Space Flight Center
IRIS	Incident Reporting Information System
IT	Information Technology
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
KSC	Kennedy Space Center
LaRC	Langley Research Center
LDAP	Lightweight Directory Access Protocol
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NESC	NASA Engineering and Safety Center
NISE	National Institute for Science Education
RDF	Raw Data File
URL	Uniform Resource Locator

12.0 References

NASA. *Problem Reporting and Corrective Action (PRACA) System Requirements*. NSTS 08126, Revision J.

NASA. *Requirements for Preparation and Approval of Failure Modes and Effects Analysis (FMEA) and Critical Items List (CIL)*. NSTS 22206, Revision D.

NASA. *JSC Problem Reporting and Corrective Action (PRACA) Requirements*. NSTS 37325.

NASA. *Nonconformance/Problem Reporting and Corrective Action (PRACA) Data Code Manual*. S00000-6-3, Revision M.

NASA. *Marshal Procedures and Guidelines QS01 Control of Nonconforming Product*. MPG 8730.3, Revision C.

NASA. *Program Problem Reporting and Corrective Action (PRACA) Requirements for Johnson Space Center Government Furnished Equipment*. JSC 28035, Revision A.

Uder, Scott J., Robert B. Stone, and Irem Y. Tumer. *Failure Analysis in Subsystem Design for Space Missions*. DETC2004/DTM-57338, Proceedings of DETC -04, 2004 ASME Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Salt Lake City, Utah.

13.0 Minority Report (dissenting opinions)

Not applicable.

VOLUME II: APPENDICES

Appendix A. Recommended Data Elements and Taxonomies for Problem Reporting

Table 1: Data Elements

Field	Share	Source	Definition	EXPECTED PROBLEM REPORT PROCESSING PHASE(S) FOR DATA FIELD POPULATION: 1=Initiation, 2=Analysis, 3=Closeout
Problem Identifier	*	Computer generated	Computer-generated unique identification number, based on some predetermined scheme	1
Problem Title	*	Limited length text string	Short description of the problem (100 -120 characters), indicating the what, when, where	1
Problem Description	*	Large text string	Detailed description of the problem - "prescription" for what would be information to be included is provided	1
Problem Type		Pick list	Categorization of the type of problem	1
Initiator POC		People Taxonomy	Name, organization, email, telephone, & role of person who initiated the problem report	1
Problem Occurrence Date	*	Formatted String	Date that problem occurred	1
Problem Occurrence Time		Formatted String	Time that problem occurred	1
Occurrence Location	*New	Text string	Geographical or orbital location of the anomalous item when problem occurred	1
Prevailing Conditions	*New	Text string	Environment in which the anomalous item existed when the problem occurred	1
Detection Date		Formatted String	Date when problem was detected	1
Detection Time		Formatted String	Time when problem was detected	1
Detection Location		Text string	Geographical or orbital location of the anomalous item when problem was detected	1
Detecting During		Text string	Description of the activity that led to detection of the problem, e.g., analysis, text, maintenance	1
Program		Taxonomy	Program name (program attributes defined in NPR 7120.5C)	1

Field	Share	Source	Definition	EXPECTED PROBLEM REPORT PROCESSING PHASE(S) FOR DATA FIELD POPULATION: 1=Initiation, 2=Analysis, 3=Closeout
Project	* (1 of 2)	Taxonomy	Project name (project attributes defined in NPR 7120.5C)	1
Mission Name		Taxonomy	Mission name within project, e.g., STS 114, GOES-N	1
Mission Type		Pick list	Type of mission	1
Lifecycle Phase	*	Pick list	Phase of mission when problem occurred	1
Vehicle/ Spacecraft Type	*	Pick list	This is either the spacecraft type or a particular vehicle name	1
Payload/Instrument Name		Taxonomy	Name given to the element within the mission that is gathering the science data	1
Payload/Instrument Type		Taxonomy	Type of instrument or payload	1
Immediate Response		Text string	Description of initial actions that were taken to respond to the problem as soon as it was discovered; e.g., remove-replace, securing	1
Failure Mode/Symptoms	*	Pick list	The manner in which an item can or actually failed to perform its required function within specified limits, under specified conditions, for a specified duration; an actual component failure/error mis-performance that was an initial event in occurrence of an anomaly; includes indications that a problem/issue exists; a way that a component failure, fault, or unsatisfactory condition becomes apparent; physical characteristics displayed by anomalous performance of a component or assembly	1-2
Defect Characteristics	*New	Example list	A fault/flaw/discrepancy/nonconformance in a component or process that causes discrepant performance of the component or assembly involved	2
Anomalous Item State	*New	Example list	Identification of the state or configuration of the anomalous item when the problem occurred	1-2
Material Involved		Example list	Identification of materials related to the anomalous item; e.g., gases, liquids	1-2

Field	Share	Source	Definition	EXPECTED PROBLEM REPORT PROCESSING PHASE(S) FOR DATA FIELD POPULATION: 1=Initiation, 2=Analysis, 3=Closeout
Recurrence Control Required?		Yes/No	Yes indicated that this problem has the potential to occur on other missions or systems - it's a generic issue	1-2
System	* as avail	Generic subsystem	Hierarchical identification for various levels to pin-point where the anomalous item fits within the system (various levels are defined in the NASA SE Handbook) - Item history includes use time & cycles, design use time & cycles, longest observed use time & cycles	1-2
SubSystem		Generic subsystem		1-2
Assembly Level		Example list		1-2
Assembly/ Component/Part Name		Many to one relationship between these levels and the higher levels beginning with Subsystem		1-2
Assembly/ Component/Part Number				1-2
Assembly/ Component/Part Serial Number				1-2
Assembly/ Component/Part Manufacturer				1-2
Assembly/ Component/Part Integrator				1-2
Item History				1-2
Hardware Criticality Code		Pick list (auto fill)	Criticality code assigned to particular hardware based on FMEA and CIL	1-2
Criticality Code	*	Pick list	Assessment of the severity of the problem based on FMEA and CIL for the assembly level … this is the functional criticality level	1-2
Item Disposition		Text string	Description of what was done with the anomalous item; e.g., repair, return to vendor	1-2
Mishap Report?		Yes/No	Did this problem result in a formal mishap report due to damage of equipment or personal injury?	1-2-3

Field	Share	Source	Definition	EXPECTED PROBLEM REPORT PROCESSING PHASE(S) FOR DATA FIELD POPULATION: 1=Initiation, 2=Analysis, 3=Closeout
Adverse Program Impact	*New	Pick list	Identification of adverse effects resulting from the problem; e.g., schedule delay, missed test date	1-2-3
Analysis POC	*	People Taxonomy	Name, organization, email, telephone, & role of person who has been assigned to analyze the problem	1-2
Previous occurrence?		Yes/No	Has this or a similar problem happened before in this mission or others?	1-2
Related Problems		Text string	Description of related problems including the problem identifiers and how this problem is different or similar to those; this could also include descriptions of noticed irregularities than did not generate formal problem records	1-2
Waiver/ Deviation?		Yes/No	Has a waiver or deviation been issued for this type problem before?	1-2
Waiver/Deviation Info		Text string	Description of applicable waivers/deviation documentation	1-2
Material Review Board?		Yes/No	Does this problem need to be referred to the Materials Review Board?	1-2
Process Escape?	*	Yes/No	Should this problem have been prevented by some established process?	1-2
Process Description	*New	Text string	Description of the process that should have prevented this problem including identification of the process & the circumstances associated with missing the problem	1-2
Requirement Violation?		Yes/No	Was this problem in violation of the functionality of the system/subsystem/assembly/component/part?	1-2
Requirement Violation Description		Text string	Description of the requirement that was violated & the mitigating circumstances	1-2
Usage Constraints		Text string	Description of the constraints that were immediately applied as a result of this problem until the problem is resolved	1-2
Applicable Documents		Example list	Identification of references/documents that are applicable to this problem; e.g., CIL, HAZ, GIDEP, FMEA	2

Field	Share	Source	Definition	EXPECTED PROBLEM REPORT PROCESSING PHASE(S) FOR DATA FIELD POPULATION: 1=Initiation, 2=Analysis, 3=Closeout
Root Cause Analysis Techniques		Example list	Identification of the root cause analysis techniques and/or tools that were used in the analysis; e.g., fault tree, Relex, Reason	2
Contributing Factor Category(s)	*New	Pick list	Classification of the contributing factor(s) for the problem	2
Contributing Factors	*	Text string	Description of the contributing factors to this problem (a contributing factor is an event or condition that may have contributed to the occurrence of an undesired outcome, but if eliminated or modified, would not by itself have prevented the occurrence) - "prescription" for what would be information to be included is provided	2
Probable Cause(s)	*	Text string	Description of the probable cause(s) for this problem (a probable cause is a factor that is believed to have contributed to or created the undesired outcome)- "prescription" for what would be information to be included is provided - either there is a root cause or a probable cause (not both)	2
Root Cause Category(s)	*	Pick list	Classification of the root cause(s) for the problem	2
Root Cause(s)	*	Text string	Description of the root cause(s) for this problem (a root cause is one of multiple factors (events, conditions, organizational factors, etc.) that contributed to or created the proximate cause and subsequent undesired outcome, and if eliminated or modified, would have prevented the undesired outcome)- "prescription" for what would be information to be included is provided - either there is a root cause or a probable cause (not both)	2
Proximate Cause Category(s)	*New	Pick list	Classification of the proximate cause(s) for the problem	2

Field	Share	Source	Definition	EXPECTED PROBLEM REPORT PROCESSING PHASE(S) FOR DATA FIELD POPULATION: 1=Initiation, 2=Analysis, 3=Closeout
Proximate Cause(s)	*New	Text string	Description of the most immediate proximate cause(s) for this problem (a proximate cause is one of multiple factors (events or conditions) that occurred, including any condition(s) that existed immediately before the undesired outcome, directly resulted in its occurrence, and, if eliminated or modified, would have prevented the undesired outcome)- "prescription" for what would be information to be included is provided	2
Expected Date Root Cause(s)		Formatted String	Expected date for determination of root cause(s)	2
Actual Date Root Cause(s)		Formatted String	Actual date for determination of root cause(s)	2
Potential Future Impact?		Yes/No	Are there potential ripple effects of this problem within this mission or other missions?	1-2
Potential Future Impact Description		Text string	Description of the potential ripple effects of this problem within this mission or other missions, including dependencies among components, existence of common components, effectivity	1-2
Resolution POC		People Taxonomy	Name, organization, email, & telephone for person responsible for resolution development	2
Implementation POC		People Taxonomy	Name, organization, email, & telephone for person responsible for implementation of the problem resolution (remedial and/or corrective)	2
Expected Date Solution Development		Formatted String	Expected date for development of solution to resolve problem (remedial and/or corrective)	2
Expected Date Solution Implementation		Formatted String	Expected date for implementation of solution to resolve problem (remedial and/or corrective)	2
Interim Resolution		Text string	Description of the problem resolution including plan of action & rationale	2

Field	Share	Source	Definition	EXPECTED PROBLEM REPORT PROCESSING PHASE(S) FOR DATA FIELD POPULATION: 1=Initiation, 2=Analysis, 3=Closeout
Interim Approval Responsibility		People Taxonomy	Name, organization, email, & telephone for person responsible for approval of interim resolution	2
Remedial Action		Text string	Description of resolution to correct the problem in its current occurrence - "prescription" for what would be information to be included is provided	2
Corrective Action	*	Text string	Description of final resolution to prevent reoccurrence of this problem or to minimize its impact - a systemic fix - "prescription" for what would be information to be included is provided	2
Residual Risk?		Yes/No	Is there remaining risk in using this item/system after implementation of final resolution (after corrective action)?	2-3
Residual Risk Description		Text string	Description of the remaining risk factors (after corrective action) in using this item/system after implementation of final resolution	2-3
Impacted Documents?		Yes/No	Are any documents invalidated or revisions required as a result of this problem?	2-3
Impacted Document Description		Text string	Description of documents that require revision as a result of this problem including title, reference number, schedule for revision, etc	2-3
Resolution Approver(s)		People Taxonomy	Name, role, date for approver(s) of final resolution that corrects the problem	2-3
Concurrence(s)		People Taxonomy	Name, role, date for people that need to concur with the resolution for this problem, e.g., ITA, review boards, project manager	2-3
Dissenting	*New	Text string	Description of reasons for non-concurrence with the problem resolution, including name, date, role of person dissenting	2-3
Problem Closeout Summary	*	Text string	Description of the problem resolution implementation including results	2-3
Actual Date Solution Development		Formatted String	Actual date(s) for development of problem solution	2

Field	Share	Source	Definition	EXPECTED PROBLEM REPORT PROCESSING PHASE(S) FOR DATA FIELD POPULATION: 1=Initiation, 2=Analysis, 3=Closeout
Actual Date Solution Implementation		Formatted String	Actual date(s) for implementation of problem solution	2
Configuration Change?	*New	Yes/No	Was there a configuration change as a result of this problem? This would generate an automatic notification to key persons.	2-3
Follow-on Action?		Yes/No	Is follow-on action required as a result of this problem (other than configuration change, i.e., procedural)?	2-3
Follow-on Action Description		Text string	Description of the follow-on actions assigned as a result of this problem including who is actionable	2-3
Lesson Learned?		Yes/No	Is there a lesson learned resulting from this problem?	2-3
Lesson Learned Description		Text string	Brief description of lesson learned from this process of identifying/working/resolving the problem, including link to lessons learned database item with more details	2-3
Notification?		Yes/No	Does the flight, ground crew, or others need to be notified of the problem?	1-2-3
Notification Identification		Text string	Identification of who needs to be notified as a result of this problem occurrence	1-2-3
Owner of anomalous item		Text string	Identification of who owns the hardware/software that experienced the problem	1-2
Problem Status	*	Pick list	Identification of the current status of this problem, e.g., open, assigned, closed	1-2-3
Last Update Field	*	Formatted String	Automatically filled by software when record saved	1-2-3 (auto)

Table 2: Pick Lists

NOTE: These are suggestions, individual projects may create other schemas or add additional values to these. Where these values are used, the definitions should be consistent.

Field	Potential Values	Definitions of Values
Problem Type	Catastrophic failure	loss of spacecraft and/or loss of crew
	Failure to meet primary objective(s)	loss of ability to meet any primary or level 1 mission requirement/objective
	Partial failure	loss of ability to meet secondary or non-level 1 mission requirement/objective, partial loss of system functionality
can apply to any level such as system, subsystem, component, etc.	Nonconformance or discrepancy	system performance is outside specifications or requirements (e.g., parameter outside a specification limit), but no adverse impact to mission requirements/objectives
	Performance degradation	adverse system performance trend (system performance degrading over time), system operating outside control limits but within specification limits
	Unexpected/unexplained performance level	as stated
	Other	specify in a text field
Mission Type	Crewed (human)	
	Uncrewed (robotic)	
	Human/robotic	
	Earth-observing	
	Planetary	
	Orbital	
	Lander	
	Solar System	
	Deep Space	
	Suborbital	
	Other	

Field	Potential Values	Definitions of Values
Vehicle/Spacecraft Type	Crewed Escape Vehicle (CEV) Crewed Launch Vehicle (CLV) Shuttle International Space Station satellite balloon rover probe launch vehicle lander sounding rocket aircraft other	This field could be used as shown in the potential values area or could contain the vehicle name such as Endeavor, Discovery in the case of Shuttle
Failure Mode/Symptoms and Proximate Causes	communication guidance & control power software electrical mechanical structural material propulsion environment contamination documentation optical thermal system interface system-human interface other	Individual projects need to go to a much lower level, this data item is intended to be a tiered effect. For example, mechanical's next tier could be: buckled, corrosion, creep (plastic deformation), ductile deformation, fatigue, fretting, galling & seizure, impact, radiation, rupture, spalling, wear. For example, electricals' next tier could be: bonding defect, breakdown, contamination, cracking, diffusion, fatigue, hot carrier induced degradation, latch-up, mask defects, noise, overstress or incorrect current magnitude, punch-through, voiding.

Field	Potential Values	Definitions of Values
Lifecycle Phase	Manufacture	terrestrial manufacture, testing, and evaluation of components and subsystems
	Assembly & Integration	terrestrial assembly, integration, and testing of the overall system
	Launch Site Operations	terrestrial launch site processing of any spacecraft (launch vehicles and payloads), design and operation of associated ground support systems, and launch control operations
	Flight Operations	includes launch ascent, on-orbit operations, in-transit operations, landing operations, and associated mission control operations
	Surface Operations	includes rover/robotic operations, surface crew operations, non-terrestrial surface manufacturing/resource production, non-terrestrial launch/landing site preparation and spacecraft processing, and associated mission control operations
	Landing Site Operations *(for reusable/recoverable systems only)*	terrestrial post-landing and/or recovery operations
	Maintenance and Refurbishment *(for reusable systems only)*	terrestrial maintenance and refurbishment of any reusable system, including reusable launch vehicles and reusable payloads/payload containers
Root Cause Category (could be contributing factors also)	Management	includes causes resulting from organizational structure, oversight, resource allocation, planning, commitment, roles/responsibilities, control of work processes, leadership of organizational culture, organizational performance measurement, internal relationship management (i.e., unions, employees), external relationship management (i.e., customers, suppliers, regulators)
	Policy	includes causes resulting from policy documentation, clarity of policy, enforceability of policy, communication of policy, basis of policy
	Communication	includes causes related to the timeliness, completeness, objectivity, and delivery of communications

Potential Values	Definitions of Values
Supervision	includes causes associated with how (well) supervisors provide leadership, rule enforcement, task preparation, employee support, etc., and how well acceptable behavior, responsibility, authority, etc. is delineated to personnel
Personnel	includes causes related to the qualifications, motivations, quantity, experience, morale, physical factors/anthropometrics, emotional factors, accepted work practices, team composition/dynamics, team composition, team adaptability/flexibility, and perceived barriers of workers
Training	includes causes related to the timeliness, completeness, currency, appropriateness of training (including system training, task training, emergency training, safety awareness training, leadership, and team skills training) as well as whether certifications are required and maintained
Work Environment	includes causes related to the work facility, platforms, and work stations - ergonomics, cleanliness, organization, temperature, humidity, etc.
Material Resources	includes causes related to support equipment, tools, parts, shop aids (reliability, usability, availability, certification, cleanliness, etc.) and procurement, logistics, and material control processes/systems.
External Environment	includes causes concerned with the external conditions experienced by the engineered system such as weather, ice, radiation, etc.
Task design & performance	includes causes resulting from error/omission, attention/distraction, complexity/difficulty, inadequate directions, insufficient response times, infrequent/unique tasks, flawed decisions of humans performing tasks, and other cognitive factors
Safety program	includes causes associated with the attention and implementation of the safety program such as its adequacy, resources, follow-through, reviews, assistance provided

Definitions of Values	Potential Values
Information system	includes causes citing the reliability, accuracy, completeness, availability of information as well as accessibility, operability of the information system
Procedures	includes causes related to the use or application of procedures, such as whether they are current, complete, accurate, understandable, consider human factors; whether they are implemented correctly; whether compliance is audited etc.
Codes, standards, guidelines	includes causes associated with the use and application of codes, standards, technical controls, and guidelines such as whether they are correctly identified, appropriate, available, accurate
Requirements/specifications definitions	includes causes citing issues with requirements or specification definitions such as whether they are complete, clear, traceable, free of conflicts, correctly flow-down/roll-up
System Design	includes issues related to the performance of system (flight systems, ground support systems, and facility systems) design such as risk identification and mitigation, modeling, analysis, testing, parametric trades, meeting requirements, defining margins, understanding uncertainties and assumptions
Risk/hazard analysis	includes issues citing the adequacy of risk modeling, tracking, and communication such as whether the management process is continuous, rigorous, timely, controlled, utilizes independent assessment
Reviews	includes causes associated with the performance of reviews such as whether they are independent, have appropriate expertise, are timely, use a corrective action system, have the correct quantity and scope
Change control	includes causes citing change control or management--whether it is thorough, uses appropriate configuration management techniques, is documented, requires new risk assessments

Definitions of Values	Potential Values
Quality control	includes causes associated with quality assurance (QA) roles and responsibilities--are there sufficient, adequate resources? what are the requirements and are they met? is QA considered and continued throughout all relevant project phases? Were appropriate statistical methods used?
Project Management	includes causes associated with schedule pressure, schedule conflicts, budget controls, etc.
Operational readiness	includes causes related to the adequacy of verification/validation activities such as integrated system tests, analysis of as-builts, proof tests
Maintenance	includes causes citing maintenance activities, preparation and implementation: have risks, like collateral damage potential, been considered? are requirements implemented, enforced, doable? Can actions be performed reliably; have human factors issues been considered? how are problems, changes handled, documented?
Inspection	includes causes citing inspection activities, preparation and implementation: have risks, like collateral damage potential, been considered? are requirements implemented, enforced, doable? Can actions be performed reliably; have human factors issues been considered? how are problems, changes handled, documented?
Anomaly resolution	includes causes related to anomaly identification, analysis, and resolution: how are precursors identified? are warning signs heeded? what is the definition of anomalous? how are differences between predicted & actual behavior handled? what is the resolution process? was it followed?
Amelioration	includes causes related to control of events once an accident or incident occurs, such as prevention of chain of events, containment, hazard control, contingency planning, use of redundancy, use of personnel protection equipment

Field	Potential Values	Definitions of Values
Criticality Code	1	Single failure that could result in death or loss of vehicle
	1R	Redundant hardware items that could cause a criticality 1 event if all items fail
	1S	Safety or hazard monitoring hardware items that could cause the system to fail to detect, combat, or operate when needed during a hazardous condition, potentially resulting in a criticality 1 event
	2	Single failure that could result in severe and/or permanent injury, major property damage, or a loss of mission
	2R	Redundant hardware items that could cause a criticality 2 event if all items fail
	3	Single failure that could result in minor injury, minor property damage, a significant mission delay, or a mission degradation in which some mission goals not achieved
	4	All other failures that result in unscheduled maintenance or repair
Adverse Program Impact	Programmatics	Problem adversely affects programmatic issues (e.g., personnel, equipment, facilities)
	Technical	Problem adversely affects the technical performance of the system
	Cost	Problem increases the expected final cost or adversely affects the budget phasing
	Schedule	Problem increases the expected length of time required to accomplish the task or mission
	Safety	Problem creates a safety issue
Problem Status	Open-Initiated	Problem initially entered into system, but no yet assigned to organization/individual for action
	Open-Assigned	Problem assigned to organization &/or individual for action but no further actions taken to date
	Open-Troubleshooting	Troubleshooting in work to identify and isolate the nonconformance
	Open-Isolated	Problem isolated to assembly/component(s) but cause not yet determined
	Open-Cause Analysis	Cause for problem determined, but corrective action not yet determined

Definitions of Values	Potential Values
Open-Corrective Action Development	Correction plan of action to address cause has been determined but not yet implemented
Open-Corrective Action Implementation	Corrective action has been implemented
Interim Disposition	Temporary dispositioned for specific components/milestones/events, but not fully resolved for entire fleet
Government Disposition Review	Disposition in government approval/review cycle
Follow-on Actions	Problem resolved, but follow-on actions remain open (e.g., related documentation update)
Closed-Action Taken	Full closed, with actions implemented to address the cause(s)
Closed-Explained	Fully closed, with approved rationale that no actions are required to address the understood issue
Closed- Unexplained	Cause not fully understood, but closed by addressing the issue as best possible through mitigation and/or resolution of probable/possible cause(s)
Hold	Issue approved for leaving unresolved and not being actively addressed at present time
Void	Problem erroneously entered and should not be present (e.g., duplicate, mistaken data entry, non-problem no nonconformance) - DATA RECORDS SHOULD NOT BE REMOVED FROM THE SYSTEM

Table 3: Examples

NOTE: These are examples, individual projects should create pick lists or links wherever possible to represent their situation. These data fields were included here because the team did not believe that even a high level set of values would be consistent between projects.			
Field	**Potential Values**		**Definitions of Values**
Anomalous Item State	Calibration mode Safe mode Open Closed		Depends on the specific characteristics of the mission components.
Assembly Level	Line-Replaceable Unit (LRU) Shop-Replaceable Unit (SRU) Crew-Replaceable Unit (CRU) Turbine Blade (NCA) Turbopump (LRU) Component Assembly Part		Depends on the specific characteristics of the mission components. Could put in name for that level of the actual assembly.
Defect Characteristics	Miswired Abraded Dinged Part omitted Worn Short-circuited Delaminated		These are definitely not an exhaustive list.
Material Involved	Consumables	Hypergolic fuel Hypergolic oxidizer Air Hydrogen Oxygen Purge gases Potable water Food Other	This envisioned to be a multi-tiered field as shown.
	Serviceable Fluids	Hydraulic fluids	
		Brake fluids	

		Other	
	Serviceable Materials	Pyros Other	
Applicable Documents	CIL xxx FMEA xxxx Lessons Learned xx		Text field with links to areas where applicable documents can be reached.
Root Cause Analysis Techniques	RELEX Fault Tree		Text field with links to areas where applicable documents can be reached.

Table 4: Taxonomies

These fields should be linked into NASA's formal taxonomies to auto-fill where possible.		
Field	**Taxonomy**	**Comments**
Imitator POC		NASA's classification project (NISE), POPS2: People, Organizations, Projects, Skills
Program		NASA taxonomy http://lurch.hq.nasa.gov/2005/11/21/pops.owl
Project		NASA taxonomy http://lurch.hq.nasa.gov/2005/11/21/pops.owl
Mission Name	STS-114 GOES-N	NASA Taxonomy does have mission names specified.
Payload/Instrument Name	MODIS GIFTS	NASA Taxonomy does have payload/instrument names specified. Individual centers also have taxonomies.
Payload/Instrument Type	telescope spectrometer imaging lidar	NASA taxonomy http://lurch.hq.nasa.gov/2005/11/21/pops.owl
Analysis POC		NASA's classification project (NISE), POPS2: People, Organizations, Projects, Skills
Resolution POC		NASA's classification project (NISE), POPS2: People, Organizations, Projects, Skills
Implementation POC		NASA's classification project (NISE), POPS2: People, Organizations, Projects, Skills
Interim Approval Responsibility		NASA's classification project (NISE), POPS2: People, Organizations, Projects, Skills
Resolution Approver		NASA's classification project (NISE), POPS2: People, Organizations, Projects, Skills
Concurrence		NASA's classification project (NISE), POPS2: People, Organizations, Projects, Skills

Table 5: Subsystem Choices

Definition for **System:**	Type of element to which the anomalous item applies. Provides context for the subsystems in the Subsystems Field.
System Name	**Definition**
Robotic Spacecraft	Any non-crewed flight system that is used to achieve a set of mission objectives. Includes items such as orbiting satellites (e.g., Terra, TDRSS and MRO), space telescopes (e.g., HST), rovers, landers, probes, and balloons.
Crewed Spacecraft	Vehicle which carries humans into space or supports them in space (e.g., Shuttle, ISS, and CEV).
Instrument/Payload/Experiment	The system or systems that are accomplishing a mission's objectives (e.g., taking science measurements or pictures). An instrument may be supported on a Spacecraft (e.g., MODIS instrument on the Terra spacecraft). It can also be the system that is being carried/supported by a Crewed Spacecraft or Launch Vehicle.
Aircraft	Missions that are carried out using an airplane or similar powered vehicle that remains in the atmosphere.
Launch Vehicle	Any type of rocket-based system that propels another vehicle from the ground (e.g., Earth, Moon, or Mars) into space. Also includes sounding rockets.
Ground System	An element that provides its support from the ground.
Other/Unknown	Not covered by other selections.
Definition for **Subsystem:**	The applicable subsystem associated with the specified System. Generally the subsystems are the first level breakdown in the hierarchy of elements that make up a System.
Subsystem Name	**Definition**
Command & Data Handling	Includes all non-GN&C flight hardware and software that support the handling, processing, and storage of data. Includes items such as the main flight computer, spacecraft bus, stored command processor, wiring harnesses, and Solid State Recorder.
Guidance, Navigation & Control	Supports attitude and orbit control of vehicle (e.g., reaction wheels, gyros, magnetic torquers, GPS receivers, etc.
Communications (RF)	Provides radio frequency communications among spacecraft and ground systems (voice and data).
Mechanical - Structures	Physical structures that comprise a vehicle, spacecraft, etc.
Mechanical - Mechanisms	Devices/hardware that enable motion, such as motors, wheels, and bearings.

Subsystem Name	Definition
Electrical Power	Provides electrical power to other systems, and manages the power overall. Includes items such as solar panels, batteries, and electrical wiring.
Propulsion	Provides ability to perform maneuvers while in orbit (e.g., attitude or orbit adjustment), as well as ascent and descent operations.
Environmental Control and Life Support	Controls and monitors the environment in which a system resides. Provides life support to humans, plants, or animals in a vehicle. Controls items such as temperature, humidity, contamination, and air quality.
Thermal	Provides active and passive methods for controlling temperature during all phases of mission.
Plumbing	Provides for the flow of liquid (e.g., water and fuel) in a vehicle, spacecraft, etc.
Pyrotechnic	Uses devices or assemblies operated by solid propellants or explosive charges to perform separation and range safety, recovery, avionics bay fire suppression, emergency jettison, radar antenna rendezvous, docking (tunnel and radiator), and crew escape.
Crew Equipment	Pertains to all end items of installed, stowed and/or worn crew-related GFE and CFE required for crew members to accomplish a mission. These end items are those which the crew member utilizes, operates, or monitors, and are required to support crew member activities from ingress through egress.
Range Safety	Provides for safety at the range, to include items such as command receiver couplers, antennas, decoders, and control distributors.
Ops Control Center	Provides commanding and telemetry processing within the ground system.
Ground Station	Ground element that provides voice and data communications between the ground system and one or more space systems.
Networks	All ground data networks (LANs/WANs) and voice communications
Front-End Processing	Ground system frame/packet processing, line outage recording, data replay, data store and forward, etc.
Data Processing/Distribution	Ground data processing of science and housekeeping data (Level 0-4), distribution of data to customers, data archival, etc.
Software	Provides a variety of flight and ground support functions, across many Systems and Subsystems.
Other/Unknown	Not covered by other selections.

Table 6: Formatted Strings

Field	Formatting
Problem Occurrence Date	mm/dd/yyyy
Problem Occurrence Time	hh:mm:ss
Detection Date	mm/dd/yyyy
Detection Time	hh:mm:ss
Expected Date Root Cause	mm/dd/yyyy
Actual Date Root Cause	mm/dd/yyyy
Expected Date Solution Development	mm/dd/yyyy
Expected Date Solution Implementation	mm/dd/yyyy
Actual Date Solution Development	mm/dd/yyyy
Actual Date Solution Implementation	mm/dd/yyyy
Last Update Field	mm/dd/yyyy; hh:mm:ss
Note: All times would be expected to be in local time.	

Appendix B. Characteristics of a Good Taxonomy for Problem Reporting

A White Paper for the NESC Taxonomy Working Group

Jayne Dutra/JPL and Tim Barth/KSC

Introduction

Effective problem reporting systems include functions beyond data reporting and collection. The overall architecture of a problem reporting system can be described by five major subsystems: the data collection system, the data analysis system, information reporting system, feedback system, and management system. The effectiveness of taxonomy design impacts all five subsystems and the overall performance (or value) of the problem reporting system.

The goal of a data system is to produce information that provides value to the users of that information. The users should gain information and insights that enable them to improve their decision-making. Taxonomies can act as a conceptual brokering layer so that data between systems can be aggregated by categories that are relevant to the user. The outcomes of improved decision-making capabilities may include improved safety, cost, and/or schedule performance.

This white paper explores the characteristics of good taxonomies for problem reporting by addressing the following three questions:

- What is a taxonomy?
- What is a *good* taxonomy?
- How do you know?

Taxonomies within information systems will change over the lifecycle of the system, so they should be considered "living" documents. However, since the impact of a taxonomy on the overall system is extensive, early investments in taxonomy design usually yield high returns.

What is a Taxonomy?

Most problem reporting systems include multiple taxonomies. A taxonomy is a "structure that provides a way of classifying things (such as living organisms, products, and books) into a series of hierarchical groups to make them easier to identify, study, and locate" [Bruno and Richmond, 2003]. The terms taxonomy, hierarchy, classification, faceted taxonomies, and ontology have overlapping and evolving meanings. These terms are discussed in the following paragraphs.

The traditional definition of taxonomy is "the study of the general principles of scientific classification, especially orderly classification of plants and animals according to their presumed natural relationships" [Merriam-Webster, 2003]. A more general description of taxonomy is "the science of classification according to a pre-determined system, with the resulting catalog used to provide a conceptual framework for discussion, analysis, and information retrieval. In theory, the development of a good taxonomy takes into account the importance of separating elements of a group (taxon) into subgroups (taxa) that are mutually exclusive, unambiguous, and taken together, include all possibilities. In practice, a good taxonomy should be simple, easy to remember, and easy to use.

Another description of taxonomy is given by "structures that provide a way of classifying things – living organisms, products, books – into a series of hierarchical groups to make them easier to identify, study, and locate" [Bruno and Richmond, 2003]. Taxonomies are said to be made up of controlled vocabulary terms. Sometimes an information architecture will contain a namespace where controlled vocabulary authority (CVA's) files are kept as the "gold source" for certain naming lists. The goal of the NASA Taxonomy is to provide a gold source for NASA Project and Mission names, for example. Taxonomies change and grow as organizations, technologies and processes change and grow.

Systematics is the "science of classification or a system of classification" and its meaning is closely related to taxonomy [Merriam-Webster, 2003]. *Classification* is "the process of classifying or a systematic arrangement in groups or categories according to established criteria" and *hierarchy* in this context is a "graded or ranked series" [Merriam-Webster, 2003]. Hierarchies consist of multiple layers or levels.

Taxonomies contain predefined hierarchies of descriptors for marking content chunks. *Faceted Taxonomies* are composed of discrete branches which are also known as *facets*. Facets are made up of hierarchically organized lists of attribute values for use in consistently labeling content components with repeatable attributes. In the past, librarians could only place a book in one location on a library shelf. Today, our electronic technology allows us the opportunity to present information from multiple viewpoints maximizing the probability of discovery of relevant information by the end user. Facets allow taxonomies to be multi-dimensional, which accommodates a wider range of content types. Taxonomies that are designed to be modular and extensible will be the most robust.

Applying values with the semantic consistency of a taxonomy enables search across multiple heterogeneous systems. If a taxonomy is meant to act as a conceptual brokering layer for data reconciliation, term development may be desirable at a broader level. The breadth of terms allows for many mapping points from various systems. Thus what one system calls a "Failure Report" may be labeled a "Problem Log" by another system, but both may fall under the broader category of "Quality Control Reports" in a brokering taxonomy. In addition, it is very possible that clues to failures may reside in repositories and systems meant to house unstructured information as well as databases. If controlled vocabulary terms are used consistently in data architectures and as values for metadata fields, then information from both sources may be correlated to give a more complete picture than the more one dimensional view that a single source can represent.

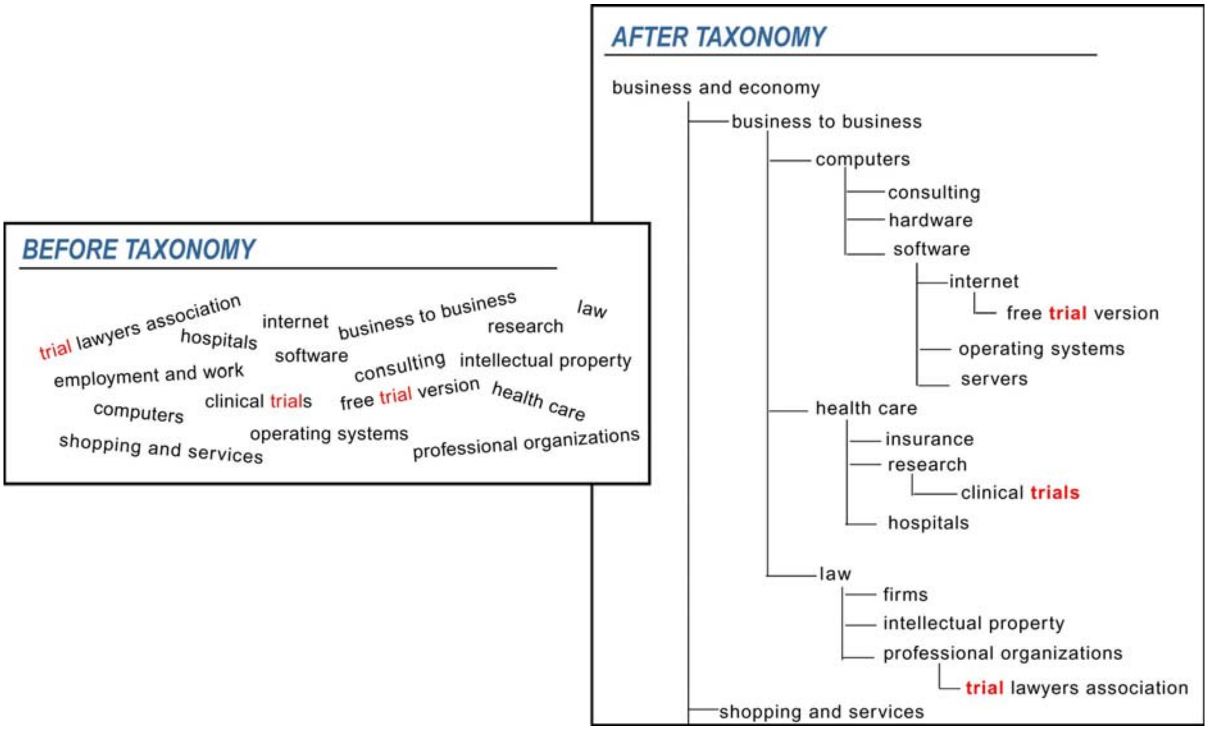

Figure 1 - Yahoo search results for "trial." From: *Taxonomy at a glance*. http://enterprise.yahoo.com/portal/services/taxonomy/taxonomy1.pdf. Last checked Jan. 6, 2003

In the last decade, *ontology* has become a fashionable term inside the knowledge engineering community, and many software tools are being developed to build ontologies that help organization of information, usually on the internet [Corcho, Fernandez-Lopez, Gomez-Perez, 2003]. In the Semantic Web world, an ontology is most often defined as a representation of a body of knowledge defined in such a way as to be consumable by systems as well as humans. Ontologies will usually incorporate some form of controlled vocabularies or taxonomies with the addition of conceptual relationships built into the schema to give it more richness and depth. If a taxonomy is built with thesauri relationships inherent in the hierarchical structure (i.e., Broader Than, Narrower Than, Related To, etc.), then it can also be considered to be an ontology and rendered in an XML logic language like OWL using predicates that explicitly express the relationships.

Ontologies can be used as interchange formats, enabling mediation between systems in a Web Services model. When implemented with controlled vocabularies and taxonomic underpinnings, ontologies enhance reusability, search results, reliability, and knowledge acquisition. Ontologies and topic maps can allow us to catalogue what we know and what we don't know, helping to shape our future research efforts as an Agency.

"*Ontology* (with an upper-case "O") is the branch of philosophy that studies the nature of existence and the structure of reality. Ontology (with a lower-case "o") investigates the categories of things that exist or may exist in a particular domain and produces a catalog that details the types of things – and the relations between those types – that are relevant for that domain" [Jacob, 2003].

What is a *Good* Taxonomy?

Developing a taxonomy is relatively easy, but developing a *good* taxonomy is usually not so easy. Think about how you organize files on your computer. By creating folders, sub-folders, and moving specific files into those folders, you are creating your own personal taxonomy for organizing information. Taxonomy design and development is usually based on a combination of science, individual and organizational experience, intuition, and art. Objective and subjective factors influence the content and structure of a taxonomy. How often do you need to search for files on your computer, even though you organized the files using a taxonomy of folders that you designed? Good taxonomies need to be designed with many current and projected users in mind.

Best Practices in Taxonomy Development

The following terms describe current industry best practices in the library science and information architecture communities for the development of robust taxonomies.

<u>Hierarchical Granularity</u>. The taxonomy is designed to provide as much depth or hierarchical granularity in the classification as the content requires. Because NASA's content includes highly technical subject matter, this allows authors to tag their material with precision, which also enables better search mechanisms and trending tools.

<u>Polyhierarchy</u>. The taxonomy allows the same concept to reappear multiple times in the scheme. Because the same concept can then have multiple parents, navigational pathways are built in that facilitate a search from numerous and different approach points. Instead of knowing exactly the right term to search on, a user can come from his or her own individual viewpoint and still locate the pertinent information.

<u>Mapping Aliases</u>. To add more richness to the labeling scheme, abbreviations and alternate terms are mapped to the taxonomy. By planning for acronyms and synonyms early on, the taxonomy becomes more accessible to users that possess a deeper grasp of any one topic area.

<u>Existing Standards</u>. Make efforts to adopt categories for standard genre and document types in the Problem Reporting Types facet of the taxonomy so that users can start with a common

understanding of what document frameworks they might be looking for. Re-use other engineering standards that the Agency might have in place for spacecraft systems and sub-systems.

One perspective on the key characteristics of a good taxonomy is that “ideal taxonomies":
- Are hierarchically structured,
- Have classes (categories) that clearly describe different aspects of the data
- Cover all subjects of interest,
- Are designed at the level of detail needed by database users, and
- Employ defined, accessible, operationally meaningful terms that can be consistently applied by database coders. [Rosenthal, 1998]

How Do You Know?

How do you know if a taxonomy is “good?” The short answer is that the taxonomy fulfills its intended function. However, there are varying degrees of “goodness,” so the characteristics of a good taxonomy should be measurable. Shappell and Wiegmann [2003] define four factors affecting the validity of taxonomy: comprehensiveness, reliability, diagnosticity, and usability. Flexibility was identified as an additional factor. An example framework for taxonomy measures/indicators based on these factors is listed below:

Comprehensiveness
- Breadth - % coverage of top-level hierarchy categories
- Completeness (Depth) - % coverage of lower-level contributing factor categories

Usability
- Subjective evaluation of reporter/coder/user to cover ease of use, intuitive structure
- Average time to complete data entry/coding after all information is collected/understood

Diagnosticity (event-specific and systemic)
- Demonstrate additional diagnostic capability/insights
- Number and effectiveness of corrective/preventive actions taken based on analysis results/recommendations
- Event specific – reduction in number and severity of recurrences
- Systemic – % improvement in performance trend over time

Reliability
- % same categories selected for one event (repeatability) – multiple reporters with similar training and experience, all with the same information

Flexibility

- % of use anticipated and unanticipated use case scenarios supported
- # of different organizations/domains able to use the taxonomy
- Presence of lower-level categories to collect additional information on most frequently occurring categories

Since some of the taxonomy measures are competing, taxonomy designers (like hardware/software system designers) must make tradeoffs. For example, increasing taxonomy comprehensiveness may decrease taxonomy usability for data reporters.

Validation

The best way to validate a taxonomy is by running a catalogue against the terms and then examining the coverage profile of the material. If there are many information objects clustered in one area of the taxonomy, the term structure may need more granularity. If there are areas of the taxonomy that are underutilized, then perhaps some term pruning needs to be done.

It is important to look at the use case scenarios for taxonomy applications. Some use cases for taxonomy applications are targeted content delivery (into a portal for example), identification of patterns in data mining, and data correlation between system objects that are not co-located. In addition, if the goal is to provide access to items in multiple heterogeneous repositories, then there should be a broader design in order to accommodate term variations.

Summary

The challenge is to optimize the taxonomy design by balancing these key performance characteristics so that the most significant attributes are revealed to the user in a mental model that is intuitive and logical.

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Appendix C. Suggested Prescriptions for Values of Key Free Text Fields

Remedial Action - Action taken to bring a specific failed unit to operational status or to eliminate an unsatisfactory condition on the specific unit; e.g., remove and replace, rework to print, material review board (MRB) disposition, etc.

The problem resolution summary for a remedial action should include the following data:

a. Problem clarification - Add sufficient narrative to describe the problem.
b. Analysis/Investigation - Include the following information:

- Troubleshooting results
- Whether problem was repeatable
- Conditions under which the problem occurred
- Analysis results
- Tests and/or efforts made to determine the problem cause
- Summary of rationale which led to a most probable cause determination
- Most probable cause

c. Problem history - Include all known failures of this failure mode. Discuss general history, and checkout history of failed unit. Use counts if there are numerous failure reports.
d. Effect on units in the field - Indicate whether the unit that failed, or a like unit, is on (or planned for) future flights.
e. Last test able to detect the problem - Indicate what test will be conducted, and when in the vehicle flow (e.g., pre-launch, countdown, etc.).
f. Methods of detecting in flight - Indicate how the crew (if manned) will be made aware of the problem, or what automatic system detects or corrects the problem.
g. Mission effect - Indicate the criticality-related effect on the mission if the problem occurred in flight, or in the launch countdown. Indicate operational workaround procedures.
h. Explanation rationale - Indicate why it is acceptable to fly or continue flying with no further corrective action. Include any test results, troubleshooting, and any other applicable information available that will further justify this rationale. If applicable, provide assurance that redundancy and/or alternate modes of operation do not negate each other. Discuss remedial action taken. If there is a valid reason why flight rationale is acceptable for only a limited number of flights, the limited effectivity and acceptable rationale shall be included for the limited flight(s).
i. Corrective/remedial action for subsequent vehicles/hardware - This item is not applicable if the explanation is for all vehicles/hardware. If the problem is closed for subsequent vehicles/hardware, indicate the documentation (configuration control board directive, engineering order number, etc.) that authorized the corrective action, and relate it to the vehicles/hardware affected.

Corrective Action - Action approved by the appropriate Government authority to correct a problem cause which includes, for example, one or more of the following dispositions:
1. Design change

2. Manufacturing method/procedure/process change
3. Facility/test equipment change
4. Test or operating procedure change
5. Training or certification of personnel
6. Maintenance procedure change
7. Limit time or cycle of component
8. Handling or shipping change.

NOTE: In addition to the above, a change in quality assurance inspection requirements may be needed.

Examples of problems that could lead to a corrective action:
a. Significant acceptance test procedure (ATP) or pre-ATP failures
b. Generic problem affecting flight hardware
c. Problem cannot be accommodated by existing flight rules/crew procedures, basic subsystem redundancy, or has other implications that present a safety of flight issue, i.e., problem is a constraint to flight
d. Other significant events

When corrective action is necessary, further reviews of the problem should be conducted, to determine if any additional data are required for assessment. Any additional procedural changes should be identified (e.g., Operations and Maintenance Requirements and Specifications Document or Flight Data File), as well as any hardware inspection or change out, or any other rationale to allow constraint removal. If no actions are identified, the constraint remains in effect until the problem is corrected or until additional information (such as failure analysis results) is obtained that justifies removal of the constraint.

The corrective action shall address all of the hardware, including those units already delivered and in the field. If previous corrective action provisions exist and did not prevent the recurrence of the problem, then those provisions shall not be acceptable for defining further corrective action provisions, and the original problem report and any related problem reports shall be reopened and readdressed.

Problem Description - A good problem description should use standard, consistent terms; minimize use of abbreviations; and include as much of the following information as is applicable –

1. The operation being performed when the anomalous condition occurred &/or was detected (i.e., What was going on?). Include a description of the configurations, i.e., switch position, valve state, pressure, temperature, etc. as well as the date and time of occurrence.
2. Description of where the anomaly occurred on the vehicle and the items that were affected by the anomaly. At a minimum should include the system/subsystem name(s)

and any other more detailed component information that is known and considered relevant to understanding the problem.

3. The organization(s)/personnel operating the anomalous item when the incident occurred/was detected (i.e., Who was working on the item?)
4. Location where the anomaly occurred/was detected (i.e., This is the physical location or environment of the vehicle, such as in-transit to or orbiting Mars, at the manufacturer, in thermal vacuum, or on-orbit - where did it happen?).
5. Any normal &/or unusual circumstances &/or parameter reading preceding or during occurrence of the anomaly (i.e., What early indications were there, if any, that something might be going wrong or might have influenced what happened?).
6. *A description of the detected symptoms that led to discovery of the anomaly. This should include a description of relevant parameter data, as applicable, (presented as "IS" and "SHOULD BE", referencing the pertinent requirement document) and/or any abnormal values or conditions. Any relevant pictures/schematics that help describe the problem should be included.*
7. The immediate actions taken to respond to the anomalous condition (i.e., What was done to immediately respond?).
8. Any potential damage/injury/abnormal conditions immediately resulting from the anomaly (i.e., What happened as a result of the anomaly?).

General Text Description Fields – Other description fields (free text) such as root cause, probable cause, proximate cause, and contributing factors should contain a detailed description of the factor including how it resulted in (or contributed to) the undesired outcome, what analyses techniques were employed to determine the relationship between the factor and the undesired outcome as well as the times and conditions associated with the occurrence.

Approval and Document Revision History

Approved:	Original signed on file	2/12/06
	NESC Director	Date

Version	Description of Revision	Author	Effective Date
1.0	Initial Release	Systems Engineering Office	1/19/06